the judgment of the trade in discriminating between different coals, I requested one of the largest miners and shippers of anthracite coal, who has for a great many years been connected with the mines over a wide area in the region, to name a number of coals, which, by most consumers, were credited with being of about equal value. Specimens of these coals were collected from one or two hundred tons, as they were ready to be shipped to market; the amount collected for each analysis, ranging in weight from one to two hundred pounds, which was then reduced by the ordinary methods now commonly used in sampling any mineral product for qualitative and quantitative tests. The number of specimens obtained in this way aggregated thirty-three. The analysis of each individual specimen is recorded in detail on p. xliv. of my 'First report of the progress of the anthracite survey,' issued by the state printer on the first of this month. For our present purpose it is not important to refer to the results in detail.

The table of averages which I have compiled shows the mean character of the coal obtained from the more important coal-beds in the Northern field in the vicinity of Wilkes Barre, in the Eastern middle (Lehigh) field in the vicinity of Hazleton, in the Western middle field in the vicinity of Shenandoah, and in the Southern field on the property of the Lehigh coal and navigation company, between Mauch Chunk and Tamaqua. These results are shown in the following table: —

No. of specimens.	Name of coal-bed.	Name of coal-field.	Chemical analysis.						Specific gravity.	Percentage of constituents of fuel.		
			Water.	Volatile matter.	Fixed carbon.	Sulphur.	Ash.	Total.		Fixed carbon.	Volatile combustible matter.	Fuel ratio, $\frac{C.}{V.H. - C.}$
3	Wharton . . .	Eastern middle .	3.713	3.080	86.404	.585	6.218	100	1.620	96.56	3.44	28.07
5	Mammoth . . .	Eastern middle .	4.119	3.084	86.379	.496	5.922	100	1.617	96.55	3.45	27.99
2	Primrose . . .	Western middle .	3.541	3.716	81.590	.499	10.654	100	1.654	95.64	4.36	21.93
5	Mammoth . . .	Western middle .	3.163	3.717	81.143	.899	11.078	100	1.657	95.62	4.38	21.83
2	Primrose? (F) .	Southern	3.008	4.125	87.982	.506	4.379	100	1.584	95.52	4.48	21.32
2	Buck-Mountain .	Western middle .	3.042	3.949	82.662	.462	9.885	100	1.667	95.44	4.56	20.93
1	Seven-foot . . .	Western middle .	3.410	3.978	80.868	.512	11.232	100	1.651	95.31	4.69	20.32
7	Mammoth . . .	Southern	3.087	4.275	83.813	.641	8.184	100	1.631	95.15	4.85	19.62
3	Mammoth . . .	Northern	3.421	4.381	83.268	.727	8.203	100	1.575	95.00	5.00	19.00

These analyses are arranged in the order of the percentage of fixed carbon in the fuel constituents.

A comparison of these results with those already referred to, as given by Taylor for the Panther-Creek basin, shows wide differences. The two Primrose and seven Mammoth specimens reported in the table for the Southern field came from the Panther-Creek basin; the average of the two Primrose coals indicating 1.29%, and the average of the seven Mammoth specimens 5.4%, less fixed carbon than Taylor's average; the minimum fixed carbon in the survey's analyses being 78 as against 86 in Taylor's table, and the survey's maximum being 88 against 92.6.

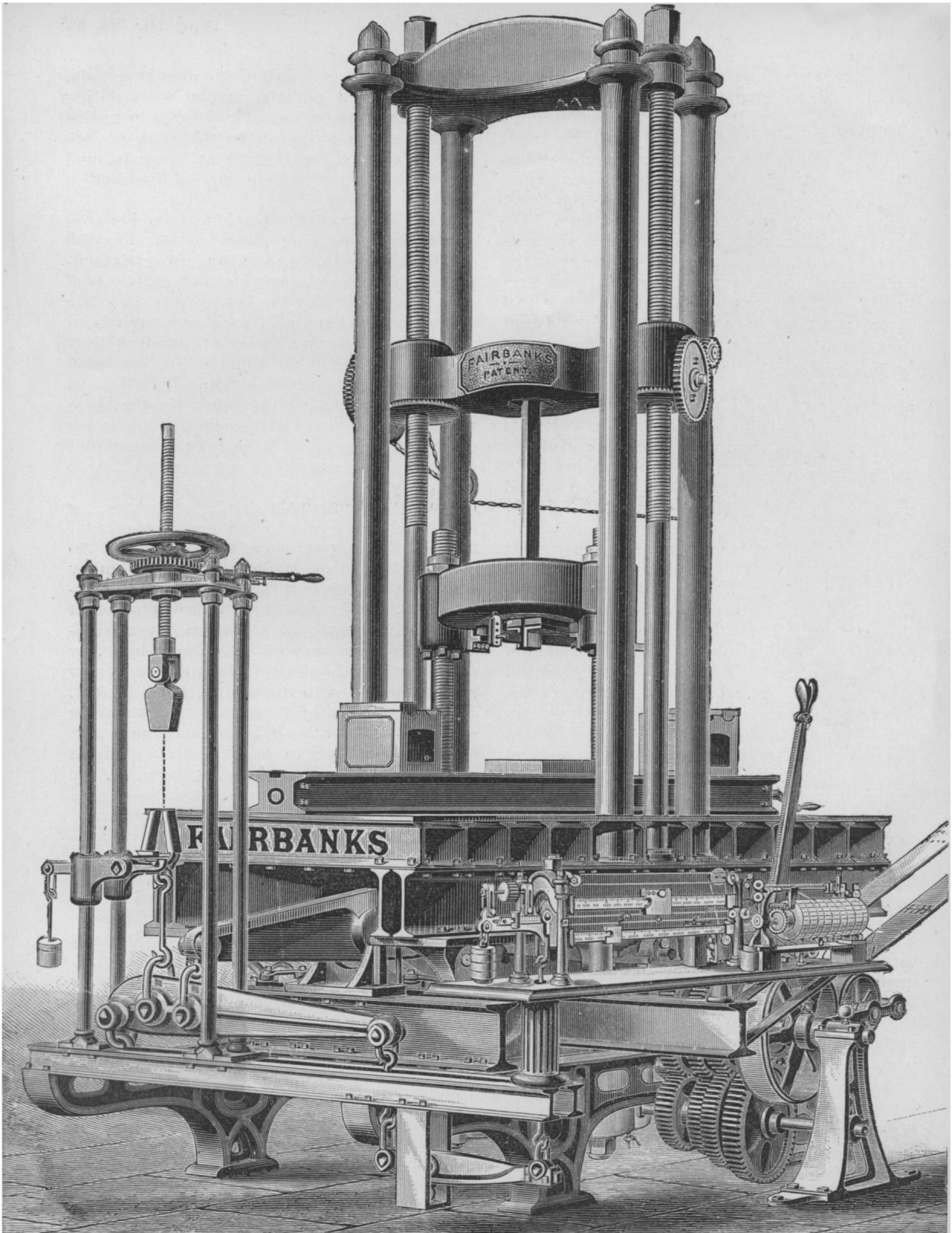
These results evidently prove, 1°, that the specimens which were collected in the past for analysis were not sampled with sufficient care; for with the improvements which have been made in breaker machinery, and the greater care exercised in the preparation of coal for market, we might reasonably expect to find the higher percentages in the more recent analyses: and, 2°, the necessity of changing the basis upon which Pennsylvania anthracite has been rated in the past.

Charles A. Ashburner.

IMPROVEMENTS IN TESTING-MACHINES.

Some philosopher has remarked that the prosperity of a nation is directly in proportion to the success of its people as constructors. According to this maxim, America occupies a very high place in the list of nations. With our almost inexhaustible ore-beds, and fertility in inventing new processes of mining and working metal, the necessity of becoming better acquainted with the properties of American building-materials is daily growing more apparent; and at present no question is exciting more attention among our constructors than that of the strength of materials.

About two years ago Messrs. Fairbanks & Co. conceived the idea of locating in New York a bureau so arranged that engineers and all interested could be afforded an opportunity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to make experiments and tests on any material, and to give to America a laboratory that should speedily become to our country what the laboratory of Kirkaldy is to England.

Fig. 1 shows the machine now employed in their department of tests and experiments. The machine stands on two cast-iron legs, supported by any suitable foundation. On these legs there rests a framework of wrought-iron I-beams, so constructed as to give the entire structure an exceedingly solid and firm basis. This framework supports a system of levers arranged in a manner similar to that of an ordinary scale, only proportioned so as to withstand the severe stresses and shocks. These levers support a secondary framework, also constructed of I-beams, and carrying four columns. On the tops of these columns stands a heavy casting, from which are suspended two side-screws, carrying the top crosshead, to which one end of the specimen to be examined may be attached. These screws are simply used as a rapid and convenient means of adjustability, so that longer or shorter specimens can be tested. This system — namely, the adjusting-screws and top crosshead — is supported upon the framework of I-beams forming the platform. Beneath the top crosshead is a second crosshead, also supported on two screws, which are placed inside the adjusting-screws. These screws extend downward through the platform, and are attached to two worm-gears firmly secured to the under side of the bottom framework. The worm-gears may be rotated in either direction, at the pleasure of the operator, by means of the belt and gears at the right hand. The worm-gears and screws form the straining-mechanism, capable of applying any stress up to two hundred thousand pounds. Great care is taken in the construction, so that no part of this mechanism whatsoever shall touch, or in any other way come in contact with, the platform, save solely and simply through the specimen to be tested: consequently all the stress produced by the crosshead on the platform must necessarily pass through the specimen; and only this amount, and no more, can be estimated on the weighing-beam.

A part of the scale system may be seen in the front of the cut; the end of one of the large levers extending under the platform, and two smaller ones carrying the stress from the end of this lever to the beam. Over the larger one of these levers are four small columns supporting a handle and lever. This apparatus is a testing-machine in miniature. The full power of the machine may be used, having a capacity of two hundred thousand pounds, reading to ten pounds, and accommodating specimens up to ten feet in length; or by means of the lever a force of ten thousand pounds may be exerted, reading to half-pounds, and accommodating specimens up to five feet in length.

The platform of the machine occupies considerable space, being some ten feet long by six feet in width. As this platform is supported on the scale, any weight which is placed on it must be felt by the beam; and, in order to test the machine, all that is necessary is to pile on the platform a series of standard test-weights.

Fig. 2 is a transverse section. Here the legs are shown supporting the beams in the same way as in the previous drawing. The lower crosshead screws, *k k*, carry the crosshead *C*, while the screws *h*, carrying the upper head, are in front of the columns *j j*. At the left may be seen the driving-apparatus for furnishing the power to the lower crosshead, the belt l^3 being arranged to slide to and fro on a tight and loose pulley. The tight pulley conveys the motion of the belt to the top driving-shaft. On this shaft there is a set of three gears, arranged in a manner very similar to the back gears of an ordinary lathe, by means of which three different speeds may be communicated to the main driving-shaft, *l*. Just to the right of these three gears may be seen a set of reversing-gears, so arranged, that, by throwing a lever to and fro, the crosshead may be run either up or down, at the will of the operator. On the driving-shaft, *l*, are placed two worms, cut, respectively, right-handed and left-handed. These match in the corresponding worm-gears which are placed at the bottom of the screws *k* and *k*. The main screws are cut right and left handed, so as to turn in opposite directions, neutralizing all the frictional stresses of the crosshead, and preventing any tendency to twist.

Perhaps the action of the machine can be well understood by supposing a test-piece in tension. The piece is secured in the top crosshead, *B*, by wedges; the other end, secured to the lower crosshead, *C*, thereby forming the only connection between the platform and the driving-mechanism. As fast as the screws are turned, stress is exerted on the specimen, which is communicated to the platform, and weighed by means of the beam at the left hand.

The results of tests are so largely dependent upon the skill of the operator, that very naturally much hesitation has been felt in accepting them as conclusive. It has been the aim,

in the design of the present machine, that as far as possible the machine should do its own work, thereby eliminating from the result all personal equation; and, supposing the machine of the machine coincide with the axis of the specimen. In making experiments on wrought iron and steel, and upon other materials which are more or less of a ductile character, this

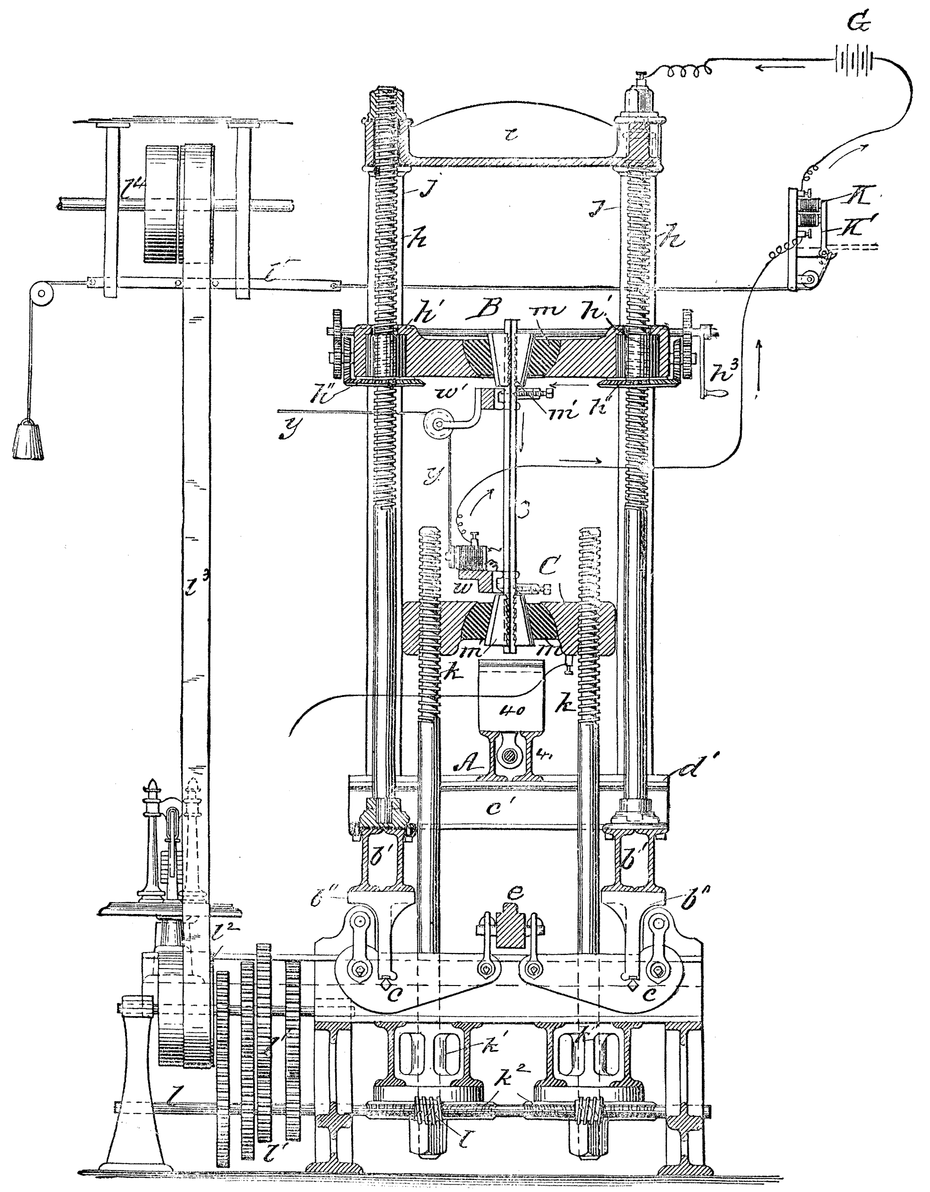

FIG. 2.

to be once correct, all subsequent records should be correct mechanically. One of the greatest obstacles to making accurate tests has been the feasibility of making the axis of stress objection is not a serious one, as it introduces but a slight error in the results. In experiments on cast-iron, cast-steel, or materials of a brittle character, the slightest cross-strain

vitiates the results, introducing stresses into the test-piece which produce an effect not to be calculated upon.

By referring to fig. 2, a device for enabling the machine to automatically centre the test-piece may be understood. The top and the bottom crossheads have in their centres a large spherical concavity. This concavity contains a segment of a sphere in which the wedges for griping the test-piece are placed. The spherical segment is made of steel turned and polished, and the concavity is lined with the best anti-friction metal. Any eccentric stress swings the segments in their sockets, and causes the axis of stress in the machine to coincide with the axis of the test-piece. The spherical segments weigh about two hundred pounds. They are, however, carefully supported on India-rubber springs, so as to eliminate as far as possible the weight of the segment from the friction in its socket. But supposing, under the most unfavorable circumstances, the whole weight of the segment does come on the joint, the coefficient of friction is not over two per cent: consequently a maximum cross-strain of four pounds on the test-piece will cause the segment to swing, and to adjust itself to the axis of stress through the piece. As this weight of four pounds is less than half the least reading of the poise, it may be assumed to produce no sensible effect on the piece to be examined.

The most of the testing-machines now in use require a careful preparation of the test-piece previous to an examination. If, for example, it is wished to ascertain the strength of an I-beam or of a channel, it is necessary to send the shape to the machine-shop, and plane a piece of one or two inches in area. This requires much time and expense. The specimen is then sent to the testing-machine and broken; and what is obtained? Simply the result of a piece cut from the shape, which may or may not give a fair knowledge of the actual strength of the member in question. What is wanted at the present time is not the strength of a carefully prepared test-piece, broken under special circumstances, but of the actual bar just as it comes from the rolls in the mill itself. The spherical segments in the crossheads of the Fairbanks testing-machine have four sides inclined at an angle of about twelve degrees to the axis of the machine. Two of these sides are curved, and two are straight. By using a number of wedges with backs correspondingly curved or straight, any piece, of whatsoever section, may be completely surrounded by the wedges, and griped on all sides; so that a channel, an angle, and I-beam, a T or a star, or, indeed, any of the shapes now rolled in the mills, may be placed in the machine and broken in full size.

Much time and labor have been spent to accomplish the power of autographically recording, at each instant of time during the experiment, the amount of stress, and the effect produced thereby on the specimen. To the best of the author's knowledge, Professor Thurston of the Stevens institute was the first to originate the idea of making a testing-machine in such a manner as to record graphically. In 1876, at the Centennial exhibition, Professor Thurston exhibited a machine designed to make tests in torsion and to record the action thereof. As a matter of history, it may be stated, that, while engaged in examining material for the East River bridge in 1877, the author designed and built the first testing-machine to autographically record results of the experiments in other stresses than that of torsion. While this machine, being the first of its kind, was necessarily crude and imperfect, it gave for some years very satisfactory results, and is still in use by the Bridge company. While the present machine is essentially different from the one just mentioned, the principles employed are the same as those devised for the East River bridge.

Referring to fig. 2, it will be seen that the battery G is attached to the top of the adjusting-screws hh. These screws are carefully insulated from the rest of the machine. As soon as the test-piece is placed in the top crosshead, it becomes thereby connected with the battery. On the lower end of the specimen may be seen a small clamp, carrying an electro-magnet. One end of the wire of this magnet is in connection with the specimen, while the other end of the wire is joined to a little binding-screw on top, to which the other pole of the battery is attached; so that the current actuating this magnet flows through the test-piece under examination. It will also be seen that the magnetic clutch, m, for holding the driving-belt on the tight pulley, is also included in this part of the battery-circuit. When the rupture of the test-piece occurs, the current is broken, the magnetic clutch is released, the belt slides by means of the counterpoise weight to the loose pulley, and the testing-machine stops. On the top of the specimen nearest to the upper crosshead is attached a second clamp, carrying a small sheave or pulley. Around this pulley, parallel to the specimen, and attached to the armature of the lower clamp magnet, passes a flexible steel tape, y, that, after passing alongside the specimen, runs

down to a pencil or stylographic pen that is carried on a sliding-track placed over a metal cylinder carrying a sheet of cross-section paper. It is obvious, that, as fast as the specimen elongates under the action of the stress, the pencil is drawn along the ways of the cylinder parallel to its axis.

Figs. 3 and 4 show the beam and registering-cylinder. In fig. 3 it will be seen that the beam consists of a single bar, sustained on a stand at one end, and enclosed in a guard at the other, while on this beam there rests a semicircular brass box forming a poise. Along the top of the beam, there is cut an exceedingly fine rack; and the motion of the poise is obtained by a pinion placed inside of the box and gearing into this rack. At the end of the beam may be seen the mercury-cups for making an electrical connection as the beam rises and falls. The operation of this piece of apparatus is substantially as follows. The clock-work motor contained in the poise, for driving it to and fro on the beam, is connected with the mercury-cups by means of some brass strips placed in the rear of the beam. These strips are connected with two electro-magnets on the inside of the poise: consequently, when the beam either rises or falls, one or the other of the magnets is excited, the corresponding train of clock-work is thrown into action, and the poise rolls to and fro until a balance is re-established. This motion of the poise to and fro on the beam is exceedingly simple, the knotty part of the problem being to correlate the motion of the poise with the motion of the cylinder exactly, so that, in a given travel of the poise along the beam, the cylinder may move a corresponding quantity. Of course, the ratio between the two movements is simply a matter of proportioning so as to accommodate the ordinary cross-section sheet to the circumference of the cylinder; but an exact and constant ratio is a very important point. Inside of the poise are two large wheels, about eight inches in diameter. The wheel placed in front is graduated with a series of numbers. The pinion carrying the poise along the beam is an inch in circumference, and consequently a single revolution of the pinion carries the poise one inch along the beam. The front wheel is secured directly to the pinion-shaft, so that there can be no back-lash between the two; and, being eight inches in diameter, one revolution of the pinion causes this dial-wheel to travel twenty-five inches of circumference. A motion of one inch along the beam corresponds to a weight of four thousand pounds. The dial-wheel being eight inches in diameter, and subdivided into four hundred parts, each of these parts corresponds to ten thousand pounds. The rear wheel of the poise is constructed in precisely the same manner as the front wheel, excepting that the marks on the dial are replaced by little strips of India-rubber, so that the wheel presents a series of teeth alternately made of India-rubber and of brass. On this wheel, there presses a brass commutator-strip, so arranged as to include the cylinder in its

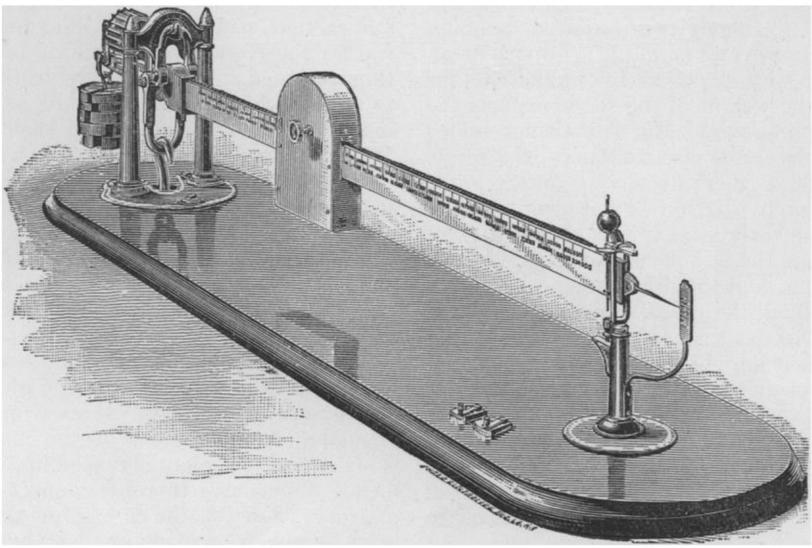

FIG. 3.

electric circuit. As soon as the poise commences to move along the beam, this wheel, with its insulated spaces, commences to turn under its commutator-strip; and with every passage of a tooth under the strip a current passes into the cylinder. Inside of the cylinder are two toothed wheels, mounted on the central shaft, and capable of being ratcheted round by means of a little lever arm and pawl, operated by a magnet placed directly under each of the wheels. locked up in a way to be absolutely exterior to any control on the part of the operator.

An old proverb has said that 'the proof of the pudding is in the eating.' In fig. 5 may be seen a half-dozen curves corresponding to as many test-pieces. The vertical scale gives the stresses, while the horizontal scale gives the normal stretches, of the pieces under examination. The two steel curves bear to each other a strong resemblance. Each commences

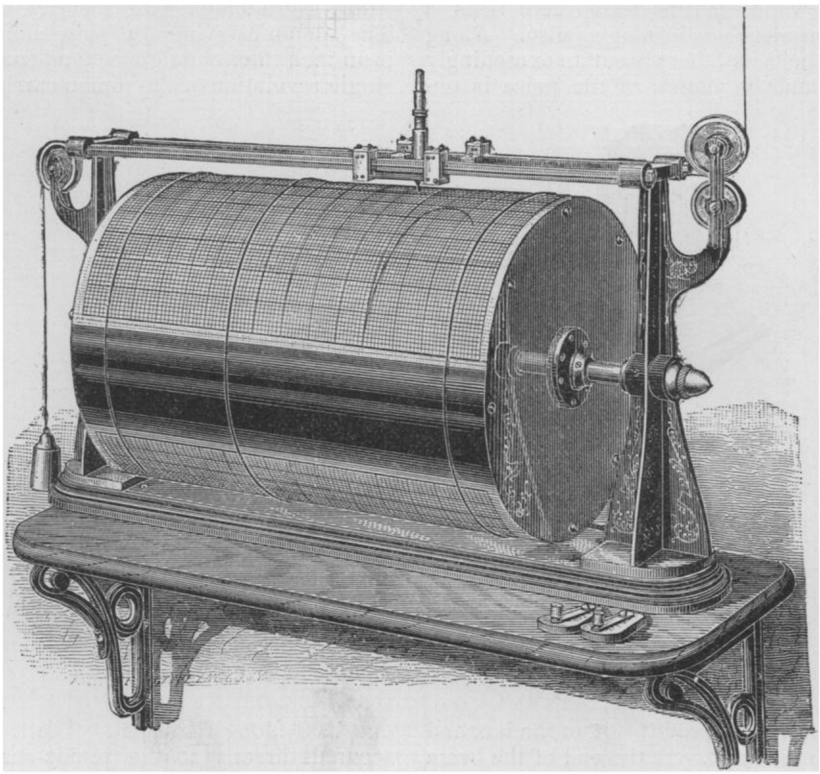

FIG. 4.

One of these wheels is intended to drive the cylinder in one direction, and the other in a contrary. One electro-magnet is connected with the mercury on the bottom of the beam, and the other in the mercury-cup on the top. As a consequence, as soon as the beam makes connection with either cup, the poise commences to travel: the corresponding electro-magnet acts, and rotates the cylinder in one way or the other. The cylinder might be placed in New York, and the registering-cylinder in Cincinnati, and the two work absolutely in harmony with each other: so, should it ever be deemed expedient, the cylinder may be enclosed or

with a line slightly inclined to the axis of stress at a constant tangent. As soon as the elastic limit is reached, a sudden point of inflection occurs. Very soon, however, there is a second point of inflection, and the curve takes on a parabolic form. The steel curves, as well as that given by the specimen of Ulster iron, may be taken to be typical forms obtained from the material which is nearly homogeneous. The lines are quite true, and without any special irregularities, until the maximum stress is reached, shortly before the specimen breaks. The stress then commences to decrease, owing to the rapid reduction of area of the piece;

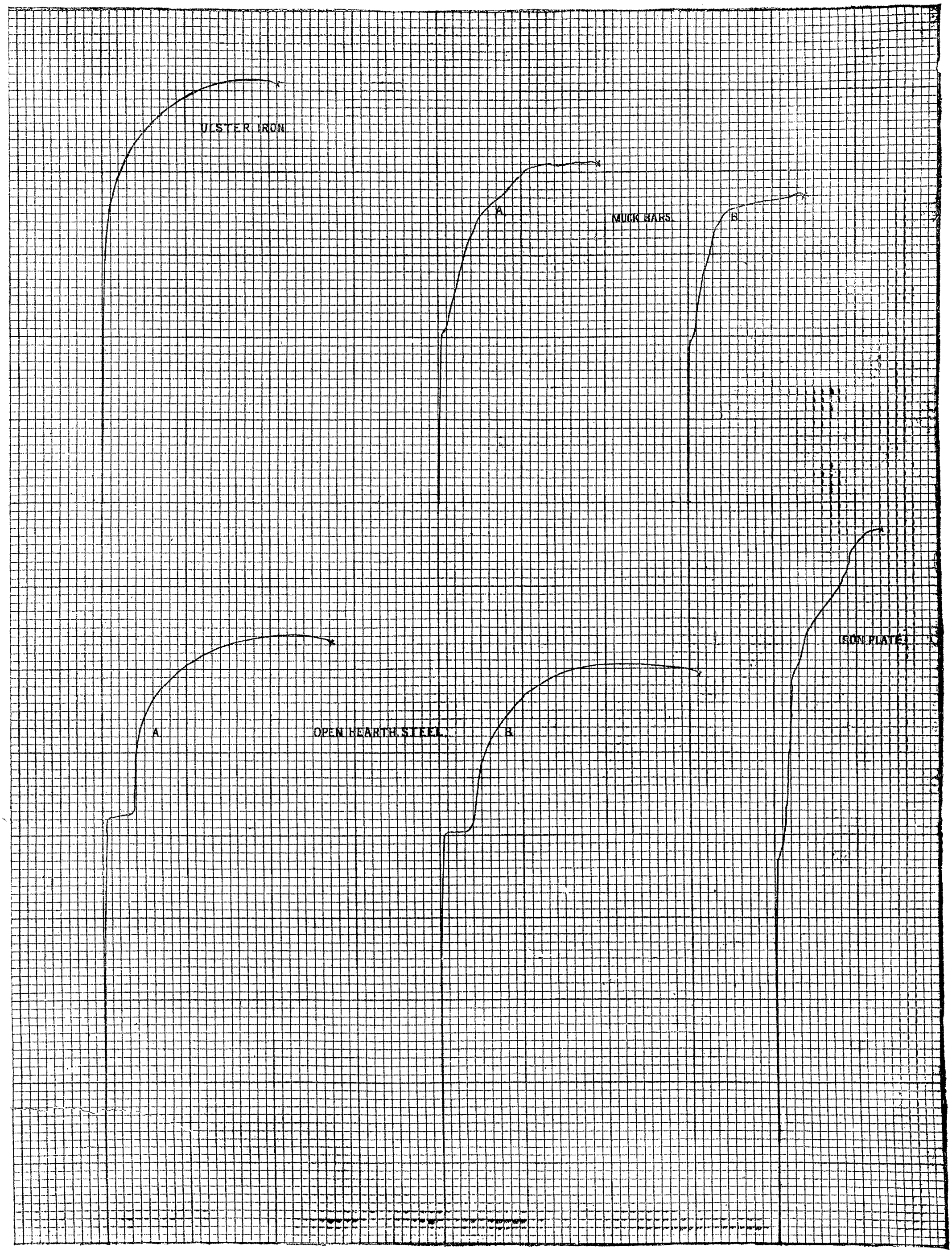

FIG. 5.—AUTOGRAPHIC RECORD ON FAIRBANKS TESTING-MACHINE.
Vertical scale, 10,000 lbs. to the inch; horizontal scale, normal stretch.

and with the reduction of the stress, the curve drops, until very shortly the specimen is ruptured, and the apparatus comes to a standstill. The other three curves are those given by a piece of boiler-plate and of a specimen of muck-bar, and are very good examples of the value of the autographic method. As is well known, both boiler-plate and muck-bar are decidedly non-homogeneous; and as a result we have curves here that are exceedingly irregular, especially after passing the elastic limit. While they bear a general resemblance to the previous ones, they are full of points of inflection, turning and twisting about, and giving one an idea that the specimen consisted of a bundle of threads or fibres which gradually parted under the action of the stress, giving any thing but a constant and uniform action.

In conclusion, a word as to the practical accuracy of the lever testing-machine may not be out of place. The machine under consideration has been subjected to severe use for nearly two years, during which time its sensitiveness, even when loaded, has not risen so high as the least reading on the poise. From this, and from long practice in similar scale-work, it may be safely stated that the testing-machine, with proper care, may have an exceedingly long life. The attainment of absolute accuracy in any department of investigation, would, if it were possible, be an extremely desirable result; yet even our best experiments are simply close approximations to the truth, and it will be granted that it is desirable to make all of our improvements commensurate towards an absolute standard of accuracy. It is of no importance to carry the weighing-power of the testing-machine beyond the possibility of the measurement of the bar. For example: supposing the tests most frequently made are those of bars having about a square inch of cross-section. In a piece of iron an error of a thousandth of a square inch of cross-section corresponds to a possible inaccuracy, in the stress produced on the bar, of fifty pounds; while the corresponding quantity in a steel bar corresponds to about seventy to ninety pounds. There are very few lathes in the country in which it is possible to turn a bar so exactly that it shall be perfectly round, and that there shall be no variation from one end to the other of more than a thousandth of a square inch. There are few men that are capable of manipulating any lathe to produce such a result; and there are still fewer gauges that are capable of measuring even a perfect bar so as to exclude the possibility of an error as great as a thousandth of a square inch. Now, if it be impossible to measure our bars to within an error of fifty to a hundred pounds in the testing-machine, is it of any importance to refine the machine beyond this reading? In the lever system of testing-machines it is perfectly possible to obtain a machine which will uniformly and constantly give readings which shall not have a greater variation than from five to twenty pounds; and, if our bars can only be measured to fifty or a hundred pounds, would it not be wiser to spend money in refining the gauges rather than in refining the machine? Again: when the consideration of the tests on the full-sized members occurs, or bars direct from the rolls, carrying with them the scale, and other imperfections from the mill, the possibility of measuring to a thousandth of a square inch becomes absurd, and two or three hundredths is the nearest approximation that can be made. In making a test of an ordinary I-bar, of, say, five or six inches of cross-section, it is certain that the bar has any thing but an absolutely uniform section from end to end; and how long, may it be asked, would it take to measure that bar from end to end, so that the least cross-section could be obtained for the record? And again: in actual experience it has been frequently found, that, having obtained what is supposed to be the least cross-section, the test-piece may break in a totally different place. It will be conceded that practical engineers care very little for test-records beyond the hundredth's place of figures; and what the country wants at the present time, is not so much testing-machines constructed with a theoretical refinement of accuracy, as a large number of practical machines, so that one may be located in every iron-works in the country, and means to carry on the experiments and to obtain from these machines a practical knowledge of what America's constructive materials really are.

A. V. Abbott.

NEW METHOD OF MOUNTING REFLECTORS.[1]

It is well known to all who have given attention to this subject, that the optical performance of great reflecting-telescopes has not been proportional to their size, and that the mechanical difficulties of keeping a large reflector in proper figure in different positions have been apparently insurmountable. A plan of supporting a large mirror, devised by Mr. Henry, has been adopted in Paris, which it is hoped may obviate this difficulty. It consists, in principle, in supporting the mirror upon a

[1] Extracted from a report to the secretary of the navy on improvements in astronomical instruments.